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VIRTUAL REALITY AT NUCLEAR ISSUES : A REVIEW STUDY

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ABSTRACT

Recently, several applications using concepts related to virtual reality has been proposed to help on solving issues of great interest in Nuclear Engineering. Among them are power plant's control rooms simulators; measurement of the estimated radiation dose in a nuclear power plant; use of game engines to create virtual environments to support evacuation planning of buildings and circulation in areas subjected to radiation; development of a man - machine interface based on speech recognition; virtual control tables for simulation of nuclear power plants; evacuation plans support; security teams training and evaluation of physical protection barriers; ergonomic evaluation of control rooms, and other ones .
Many of these applications are developed at Instituto de Engenharia Nuclear (IEN), having their results published in form of articles in periodicals and conferences. This article presents a review of some of these studies showing the evolution in the use of these concepts, describing some of its results and showing prospects for future applications that can make use of virtual reality technology.

1. INTRODUCTION

The use of virtual reality based simulations has becoming more and more common at research on nuclear issues along the recent years. This technology can be found in a large range of applications such as virtual controlling rooms for ergonomic studies and man/machine interface evaluation (Gatto, 2012); mapping and evaluation of dose assessment in nuclear plants (Mól et. al, 2009); modeling of control desks for plant operators training (Aghina et. al, 2007); simulations to support evacuation planning (Mól et. al, 2007, 2008); training of security staff and evaluation of physical protection barriers in nuclear facilities (Augusto et. al, 2009; Jorge et. al, 2011); support on planning physical security (Silva et. al, 2015), development of virtual devices for radiological detection (Sobrinho, 2013) and several others.
Due to the importance of the previous mentioned applications this work proposes to perform a review on some of such, particularly the ones developed at Instituto Nuclear de Engenharia (IEN). IEN is a research institute of the Comissão Nacional de Energia Nuclear (CNEN). IEN facilities include a research nuclear reactor, particle accelerators, and chemical laboratories. It is also the most important government agency for nuclear waste management at Rio de Janeiro.

The objective of this study is give chronological information about some of the already published works related to the use of VR at nuclear research field. To do so, there were identified five major areas where such applications can be found. They are: nuclear power plant operators training/ ergonomic studies; dose assessment; safety training/ physical security; development of virtual devices and nuclear waste treatment. The basic characteristics of each are discussed, accompanied by a brief resume of obtained results in each of them besides of showing a perspective of new implementations for future works.
The article is organized follows: chapter 2 describes an overview of the applications concerning to the use of VR at nuclear issues; chapter 3 shows a brief discussion about the works referred on previous chapter; finally, chapter 4 presents the conclusion and final considerations.

2. REVIEW OF VIRTUAL REALITY TECHNIQUES USED AT NUCLEAR ISSUES

VR based technologies are found in a large range of applications such as training, simulations or even on the development of virtual devices as shown by Sobrinho (2013). For this reason, not only nuclear researchers have adopted these techniques in their surveys being easy to find some works at the treatment of psychological diseases, just to give an example. There is a great deal of uses of VR concepts available at the literature along the recent years, some of them developed at Instituto de Engenharia Nuclear (IEN). A brief glance of a few amount of such is described next:

2.1 Nuclear Power Plant Operators Training/ Ergonomic Studies

Nuclear power plant (NPP) operators training is not a trivial task. In the past, it was performed using physical copies of NPP control desks, with the same layout as the real ones. However, these copies were large and expansive which motivated the search for a more suitable procedure. According to this objective, Aghina et al (2008) have proposed the use of virtual control desks for NPP simulations. Thus they create a cheaper and more practical alternative to the traditional method used until then.
Another work referred to the training of operators using VR techniques is shown in Aghina et al (2007) where a full scope simulator of a NPP control room was proposed. The ergonomic evaluation (Aghina et al, 2008) verifies whether the design stage has adequately considered ergonomic and human-factors requirements. The authors also state that "a system’s hardware and software might be well designed, but whether its operators can easily execute their tasks depends on how the system presents information to them" (Aghina et al, 2008).
Giving the importance of the ergonomic aspects, Gatto (2012) and Luquetti et al (2013) have also performed surveys related to this topic. The former presents an ergonomic evaluation of NPP control rooms using VR techniques while the latter proposes to virtually simulate a NPP control room for ergonomic evaluation purposes;

2.2 Radioactive Dose

One of the most important application of VR at nuclear issues is that referred to estimate radiation dose levels. Due to the fact that it's harmful for all living things, proceed with real tests is not an option in this case. Specifically for NPPs, a better planning of operational and maintenance tasks execution can reduce the dose received by personnel as required by ALARA ("As Low As Reasonable Achievable") principle (Mól, 2011).

Viewing that VR technology can provide immersive and interactive experiences, it has been used as a tool also to deal with this important subject. Augusto et al (2007) have shown a way to use VR to make estimative measures on radioactive dose rates in NPPs, thus avoiding the need to expose the workers to dangerous situations when performing this task.
Other similar application can be found in Mól et al (2008) where studies on NPPs dose assessment simulations are carried out inside virtual environments. Mól et al (2011) have proposed a more sophisticated procedure concerning to this question by using neural networks coupled with VR techniques to make a radiation dose rate map interpolation.
Following this chronological report, the improvement of this tool is made clear. Besides previous offline or online dose rate data, a finer dose rate distribution is also available (Mól et al, 2011). It is detached that this application has an embedded intelligent system for dose prediction which assures that it can be further developed on future surveys;

2.3 Safety Staff Training/ Physical Security

Another very important use of VR technology at nuclear issues concerns to both, safety personnel training and physical security subjects. This area has the major number of works published by IEN researchers in comparison to the other ones. Mól et al (2007) have shown a study using a game engine to create virtual environments in which actions concerning to supporting, evacuation planning and walkthrough at possibly contaminated areas can be performed. That was one of the first prototypes developed at IEN which such purposes. An improvement of this application was presented at (Mól et al, 2008) where IEN building has been modeled in 3D to perform evacuation tests simulating emergency situations. As nuclear plants represent just one of the many environments where virtual simulations might be the best or even the only way to evaluate critical situations or conditions too dangerous to search by trial at real ones, as in the presence of fire and smoke, radioactive or chemical contamination, this kind of use for VR technologies plays a major role.
In 2009 (Augusto et al, 2009) a new approach of VR techniques for training of the safety staff was proposed. The main difference to the previous mentioned ones was the fact of considering the evaluation of physical protection barriers in nuclear facilities. It can be viewed as an improvement on simulated environments for nuclear concerns, as physical security was not considered for analysis in any of the works developed at IEN until then. In other words, to evaluate a new parameter, i,e., physical security, the method has become more close to the reality, achieving a more reliable feature.

2.4 Development of Virtual Devices

The need to improve procedures or to accomplish tasks in a more practical way are some of the possible reasons to the development and implementation of virtual devices. As an example of the first case, Jorge et al (2007) have proposed the development of a Man Machine Interface based on speech recognition. Thus, each action corresponds to a spoken command which means that are not manual interventions.
It is intended to be used to execute commands in a NPP control room as well as to make the interactions in virtual environments easier. Relevant parameters are extracted from speech signals that are used as inputs of a neural network in order to perform their recognition. Although the results had shown a need for further improvements, it's important to highlight how useful can be such sort of application for using at cell phones, security systems or even criminal investigations.

Giving an example of the second case, Sobrinho (2013) has proposed an approach using VR to read the superheated emulsion detector (a.k.a. bubble detector) in a more suitable way. Such device is capable to provide a measure of its interaction with neutronic activity fields instantaneously, being helpful on radiological protection.
Furthermore, it is the only neutron dosimeter in which the answer does not depend on the dose energy pattern, being not affected by gamma radiation. There are several applications where bubble detectors can be found such as in nuclear power plants, nuclear energy labs, hospitals using radiological treatment and others.
There are two advantages when comparing the virtual prototype to its real match: the relatively low cost concerning to acquisition, maintenance and periodic calibrations besides the fact it gives to the user a more reliable viewing of the bubbles, thus avoiding counting mistakes related to bubble superposition, just to exemplify. It is made possible due to the assistance of stereo vision and 3D navigation resources to perform the marking and counting the total amount of bubbles. As a bubble detector is used for radiological detection, it's utterly that are not mistakes on counting the bubbles. This kind of application contributes to validate the importance on using VR techniques to improve some of the devices and procedures available nowadays.

2.5 Nuclear Waste Treatment

The nuclear waste management must be a worry for everyone who deals with nuclear issues. It's true that to generate electricity by nuclear fission is safer than regular methods using charcoal or oil referring to the greenhouse effects or atmospheric pollution. However, it's also true that radioactive waste like the one produced by a NPP emits ionizing radiation, which is potentially dangerous to both human health and the environment.
Concerning to this subject, Freitas et al (2014) have proposed operational procedures in radioactive waste deposits using VR techniques in order to enable simulations of virtual relocation in these deposits. As a first case study they have modeled a virtual nuclear waste repository. With the development of a deposit's virtual model, it was possible to simulate virtual/train allocation and reallocation of low and medium level waste materials. It's also possible to make displacements for virtual objects and dynamic calculation of the radiation rate inside this environment. Through virtual simulations the dose accumulated by a virtual person (a.k.a. avatar) in procedures performed inside the virtual environment can be achieved, since each virtual object in the tank is a source of radiation.

3. DISCUSSION

A number of studies have been performed considering the most diverse applications of VR techniques for nuclear issues referred to both, propose new approaches and improve already available ones. Particularly, this review study has considered just the works developed at Instituto de Engenharia Nuclear (IEN), a research facility located at Rio de Janeiro, Brazil. To proceed with this review the analyzed works were organized in five great areas of study, namely: nuclear power plant operators training/ ergonomic studies; dose assessment; safety training/ physical security; development of virtual devices and nuclear waste treatment.
Table 1 shows a comparison of the total number of publications considered at this survey related to the area each one of it belongs to.

Table 1: Comparative by number of publications

Area	Number of Publications since 2007
Nuclear power plant operators training/ ergonomic studies	4
Dose assessment	4
Safety training/ physical security	6
Development of virtual devices	2
Nuclear waste treatment	1

According to the information provided by table 1 data, the survey using VR techniques as of 2007 has given rise to several works at IEN. The different amount of publications denotes a major degree of development of some areas like safety training/ physical security, nuclear power plant operators training/ ergonomic studies and dose assessment which together correspond to more than 80% of that in comparison to the other two, development of virtual devices and nuclear waste treatment which does not mean that an area is more important than the others.

4. CONLUSION

This review has presented the state-of-the-art from 2007 to 2015 of using VR techniques at nuclear issues by researchers of Brazilian's facility IEN. From the examined literature, it is clear that the use of VR has provided the development of very interesting and useful applications concerning to this branch of science. It has been shown applications concerning to personnel training; physical security evaluation; ergonomic analysis; radioactive dose assessment; speech recognition; evacuation planning; nuclear waste management etc., each of them using VR concepts.

At present, new surveys are taking place where more advanced softwares and game engines will not only provide a more realistic interaction inside the virtual environment used for training but it will also allows the user to experience a more reliable feeling of immersion using devices like oculus RIFT, for instance. Another interesting characteristics of the VR technologies is the fact that already finished works can be improved according to the development of computational resources which grants more detailed environments allied to more natural avatar and vehicles movements with a minor effort of the equipment.

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